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1. INTRODUCTION

1.1 BACKGROUND

Because of differences in physiology and behaviors, exposures among children are expected to be different than among adults. Children may be more highly exposed to environmental toxicants than adults, because they consume more food and water, and have higher inhalation rates per unit of body weight, and have higher surface area to volume than adults. Also, young children play close to the ground and are more likely to come into contact with contaminated soil outdoors and with contaminated dust on surfaces and carpets indoors. Children may also be exposed to contaminants as a result of hand-to-mouth and object-to-mouth activities as a result of behaviors existing during certain phases of childhood. As another example, exposure to chemicals in breast milk affects specifically infants and young children. In terms of risk, children may also be more vulnerable to environmental pollutants because of differences in absorption, excretion, and metabolism (U.S. EPA, 1997a).

In April, 1997, President Clinton signed an Executive Order to Protect Children from Environmental Health Risks and Safety Risks. The Order requires all federal agencies to address health and safety risks to children, coordinate research priorities on children's health, and ensure that their standards take into account special risks to children. To implement the President's Executive Order, EPA established the Office of Children's Health Protection (OCHP), and offices within EPA increased their efforts to provide a safe and healthy environment for children by ensuring that all regulations, standards, policies, and risk assessments take into account risks to children. Recent legislation, such as the Food Quality Protection Act and the Safe Drinking Water Act amendments, has made children's health issues more explicit and research on children's health issues is continually expanding. As a result of the emphasis on children's risk, the EPA Office of Research and Development's (ORD) National Center for Environmental Assessment (NCEA) issued a Children's Risk Policy, which emphasized the need to evaluate exposures and risks among this population and ORD developed a Strategy for Research on Risks to Children (Children's Research Strategy) (U.S. EPA, 1997a; 1999a). The goal of the Children's Research Strategy is to improve risk assessments for children. This *Child-specific Exposure Factors Handbook* is intended to support EPA/ORD/NCEA's efforts to improve exposure and risk assessments for children.

In 1997, EPA/ORD/NCEA published the *Exposure Factors Handbook* (U.S. EPA, 1997b). The Handbook includes exposure factors and related data on both adults and children. OCHP's recently-issued its child-related risk assessment policy and methodology guidance document survey (U.S. EPA, 1999b), highlighted the *Exposure Factors Handbook* (U.S. EPA, 1997b) as a source of information on exposure factors for children. EPA's *Children's Environmental Health Yearbook* (U.S. EPA, 1998) also listed the *Exposure Factors Handbook* as a source of exposure information for children. However, the EPA Program Offices identified the need to consolidate all children exposure data into one document. The goal of this *Child-specific Exposure Factors Handbook* is to fulfill this need. This Handbook provides non-chemical-specific data on exposure factors that can be used to assess doses from dietary and non-dietary ingestion exposure, dermal exposure, and inhalation exposure among children.

This handbook provides exposure factors for children in the following areas:

- breast milk ingestion;
- food ingestion, including homegrown foods and other dietary-related data;
- drinking water ingestion;
- soil ingestion;
- rates of hand-to-mouth and object-to-mouth activity;
- dermal exposure factors such as surface areas and soil adherence;
- inhalation rates;
- duration and frequency in different locations and various microenvironments;
- duration and frequency of consumer product use;
- body weight data; and
- duration of lifetime.

This handbook is a compilation of available data from a variety of sources. Most of these data have been described in detail in EPA's *Exposure Factors Handbook* (1997b), but data that have been published subsequent to release of the *Exposure Factors Handbook* are also presented. With very few exceptions, the data presented are the analyses of the individual study authors. Since the studies included in this handbook varied in terms of their objectives, design, scope, presentation of results, etc., the level of detail, statistics, and terminology may vary from study to study and from factor to factor. For example, some authors used geometric means to present their results, while others used arithmetic means or distributions. Authors have sometimes used

different age ranges to describe data for children. Within the constraint of presenting the original material as accurately as possible, EPA has made an effort to present discussions and results in a consistent manner. Further, the strengths and limitations of each study are discussed to provide the reader with a better understanding of the uncertainties associated with the values derived from the study.

1.2 PURPOSE

The purpose of the *Child-specific Exposure Factors Handbook* is to: (1) summarize key data on human behaviors and characteristics which affect children's exposure to environmental contaminants, and (2) recommend values to use for these factors. These recommendations are not legally binding on any EPA program and should be interpreted as suggestions which program offices or individual exposure assessors can consider and modify as needed. Most of these factors are best quantified on a site or situation-specific basis. The data presented in this handbook have come from various sources, including the EPA's *Exposure Factor Handbook* (U.S. EPA, 1997b), government reports, and information presented in the scientific literature. The handbook has strived to include discussions of the issues which assessors should consider in assessing exposure among children, and may be used in conjunction with the EPA document: EPA/600/R-99/060 July 1999, entitled *Socio-demographic Data Used for Identifying Potentially Highly Exposed Subpopulations of Children*, which is currently being drafted and provides population data for children.

1.3 INTENDED AUDIENCE

The *Child-specific Exposure Factors Handbook* may be used by exposure assessors inside the Agency as well as outside, who need to obtain data on standard factors needed to calculate childhood exposure to toxic chemicals.

1.4 SELECTION OF STUDIES FOR THE HANDBOOK

Information in this handbook has been summarized from studies documented in the scientific literature and other available sources. Studies were chosen that were seen as useful and appropriate for estimating exposure factors. The handbook contains summaries of selected studies published through 2000.

General Considerations

Many scientific studies were reviewed for possible inclusion in this handbook. Generally, studies identified in the *Exposure Factors Handbook* (U.S. EPA, 1997b) as key studies were also included in this children's document. New studies that became available after publication of the *Exposure Factors Handbook* were also included. Key studies from the *Exposure Factors Handbook* were generally defined as the most useful for deriving exposure factors. The recommended values for most exposure factors are based on the results of these studies. As in the *Exposure Factors Handbook*, the key studies were selected based on the following considerations:

- *Level of peer review*: Studies were selected predominantly from the peer-reviewed literature and final government reports. Internal or interim reports were therefore avoided.

- *Accessibility*: Studies were preferred that the user could access in their entirety if needed.

- *Reproducibility*: Studies were sought that contained sufficient information so that methods could be reproduced, or at least so the details of the author's work could be accessed and evaluated.

- *Focus on exposure factor of interest*: Studies were chosen that directly addressed the exposure factor of interest, or addressed related factors that have significance for the factor under consideration. As an example of the latter case, a selected study contained useful ancillary information concerning fat content in fish, although it did not directly address fish consumption.

- *Data pertinent to the U.S.*: Studies were selected that addressed the U.S. population. Data from populations outside the U.S. were sometimes included if behavioral patterns and other characteristics of exposure were similar.

- *Primary data*: Studies were deemed preferable if based on primary data, but studies based on secondary sources were also included where they offered an original analysis. For example, the handbook cites studies of food consumption based on original data collected by the USDA National Food Consumption Survey.

- *Current information*: Studies were chosen only if they were sufficiently recent to represent current exposure conditions. This is an important consideration for those factors that change with time.

- *Adequacy of data collection period*: Because most users of the handbook are primarily addressing chronic exposures, studies were sought that utilized the most appropriate techniques for collecting data to characterize long-term behavior.

- *Validity of approach*: Studies utilizing experimental procedures or approaches that more likely or closely capture the desired measurement were selected. In general, direct exposure data collection techniques, such as direct observation, personal monitoring devices, or other known methods were preferred where available. If studies utilizing direct measurement were not available, studies were selected that rely on validated indirect measurement methods such as surrogate measures (such as heart rate for inhalation rate), and use of questionnaires. If questionnaires or surveys were used, proper design and procedures include an adequate sample size for the population under consideration, a response rate large enough to avoid biases, and avoidance of bias in the design of the instrument and interpretation of the results.

- *Representativeness of the population*: Studies seeking to characterize the national population, a particular region, or sub-population were selected, if appropriately representative of that population. In cases where data were limited, studies with limitations in this area were included and limitations were noted in the handbook.

- *Variability in the population*: Studies were sought that characterized any variability within populations.

- *Minimal (or defined) bias in study design*: Studies were sought that were designed with minimal bias, or at least if biases were suspected to be present, the direction of the bias (i.e., an over or under estimate of the parameter) was either stated or apparent from the study design.

- *Minimal (or defined) uncertainty in the data*: Studies were sought with minimal uncertainty in the data, which was judged by evaluating all the considerations listed above. At least, studies were preferred that identified uncertainties, such as those due to inherent variability in environmental and exposure-related parameters or possible measurement error. Studies that documented Quality Assurance/Quality Control measures were preferable.

1.5 APPROACH USED TO DEVELOP RECOMMENDATIONS FOR EXPOSURE FACTORS

As discussed above, EPA first reviewed all literature pertaining to a factor and determined key studies. These key studies were used to derive recommendations for the values of each factor. The recommended values were derived solely from EPA's interpretation of the available data. Different values may be appropriate for the user to select in consideration of policy,

precedent, strategy, or other factors such as site-specific information. EPA's procedure for developing recommendations was as follows:

1. Key studies were evaluated in terms of both quality and relevance to specific populations (general U. S. population, age groups, gender, etc.). The criteria for assessing the quality of studies is described in Section 1.4.
2. If only one study was classified as key for a particular factor, the mean value from that study was selected as the recommended central value for that population. If there were multiple key studies, all with reasonably equal quality, relevance, and study design information were available, a weighted mean (if appropriate, considering sample size and other statistical factors) of the studies were chosen as the recommended mean value. If the key studies were judged to be unequal in quality, relevance, or study design, the range of means were presented and the user of this handbook must employ judgment in selecting the most appropriate value for the population of interest. In cases where the national population was of interest, the mid-point of the range was usually judged to be the most appropriate value.
3. The variability of the factor across the population was discussed. If adequate data were available, the variability was described as either a series of percentiles or a distribution.
4. Limitations of the data were discussed in terms of data limitations, the range of circumstances over which the estimates were (or were not) applicable, possible biases in the values themselves, a statement about parameter uncertainties (measurement error, sampling error) and model or scenario uncertainties if models or scenarios have been used in the derivation of the recommended value.
5. Finally, EPA assigned a confidence rating of low, medium or high to each recommended value. This rating is not intended to represent an uncertainty analysis, rather it represents EPA's judgment on the quality of the underlying data used to derive the recommendation. This judgment was made using the guidelines shown in Table 1-1. Table 1-1 is an adaptation of the General Considerations discussed earlier in Section 1.4. Clearly this is a continuum from low to high and judgment was used to determine these ratings. Recommendations given in this handbook are accompanied by a discussion of the rationale for their rating.

Table 1-2 summarizes EPA's recommendations and confidence ratings for the various exposure factors that apply to children.

It is important to note that the study elements listed in Table 1-1 do not have the same weight when arriving at the overall confidence rating for the various exposure factors. The relative weight of each of these elements depend on the exposure factor of interest. Also, the relative weights given to the elements for the various factors were subjective and based on the professional judgement of the authors of this handbook. In general, most studies would rank high with regard to "level of peer review," "accessibility," "focus on the factor of interest," and "data pertinent to the U.S." These elements are important for the study to be included in this handbook. However, a high score of these elements does not necessarily translate into a high overall score. Other elements in Table 1-1 were also examined to determine the overall score. For example, the adequacy of data collection period may be more important when determining usual intake of foods in a population. On the other hand, it is not as important for factors where long-term variability may be small such as tapwater intake. In the case of tapwater intake, the currency of the data was a critical element in determining the final rating. In addition, some exposure factors are more easily measured than others. For example, soil ingestion by children is estimated by measuring, in the feces, the levels of certain elements found in soil. Body weight, however, can be measured directly and it is, therefore, a more reliable measurement. This is reflected in the confidence rating given to both of these factors. In general, the better the methodology used to measure the exposure factor, the higher the confidence in the value.

1.6 CHARACTERIZING VARIABILITY

This document attempts to characterize variability of each of the factors. Variability is characterized in one or more of three ways: (1) as tables with various percentiles or ranges of values; (2) as analytical distributions with specified parameters; and/or (3) as a qualitative discussion. Analyses to fit standard or parametric distributions (e.g., normal, lognormal) to the exposure data have not been performed by the authors of this handbook, but have been reproduced in this document wherever they were found in the literature. Recommendations on the use of these distributions are made where appropriate based on the adequacy of the supporting data. The list of exposure factors and the way that variability has been characterized (i.e., average, upper percentiles, multiple percentiles, fitted distribution) are presented in Table 1-3.

The term upper percentile is used throughout this handbook and it is intended to represent values in the upper tail (i.e., between 90th and 99.9th percentile) of the distribution of values for a particular exposure factor.

An attempt was made to present percentile values in the recommendations that are consistent with the exposure estimators defined in the Exposure Guidelines (i.e., mean, 50th, 90th, 95th, 98th, and 99.9th percentile). This was not, however, always possible because either the data available were limited for some factors, or the authors of the study did not provide such information. It is important to note, however, that these percentiles were discussed in the Exposure Guidelines within the context of risk descriptors and not individual exposure factors. For example, the Guidelines stated that the assessor may derive a high-end estimate of exposure by using maximum or near maximum values for one or more sensitive exposure factors, leaving others at their mean value.

The use of Monte Carlo or other probabilistic analysis require a selection of distributions or histograms for the input parameters. Although this handbook is not intended to provide a complete guidance on the use of Monte Carlo and other probabilistic analyses, the following should be considered when using such techniques:

- The exposure assessor should only consider using probabilistic analysis when there are credible distribution data (or ranges) for the factor under consideration. Even if these distributions are known, it may not be necessary to apply this technique. For example, if only average exposure values are needed, these can often be computed accurately by using average values for each of the input parameters. Probabilistic analysis is also not necessary when conducting assessments for screening purposes, i.e., to determine if unimportant pathways can be eliminated. In this case, bounding estimates can be calculated using maximum or near maximum values for each of the input parameters.

- It is important to note that the selection of distributions can be highly site specific and will always involve some degree of judgment. Distributions derived from national data may not represent local conditions. To the extent possible, an assessor should use distributions or frequency histograms derived from local surveys to assess risks locally. When distributional data are drawn from national or other surrogate population, it is important that the assessor address the extent to which local conditions may differ from the surrogate data.

In addition to a qualitative statement of uncertainty, the representativeness assumption should be appropriately addressed as part of a sensitivity analysis.

- Distribution functions to be used in Monte Carlo analysis may be derived by fitting an appropriate function to empirical data. In doing this, it should be recognized that in

the lower and upper tails of the distribution the data are scarce, so that several functions, with radically different shapes in the extreme tails, may be consistent with the data. To avoid introducing errors into the analysis by the arbitrary choice of an inappropriate function, several techniques can be used. One way is to avoid the problem by using the empirical data itself rather than an analytic function. Another is to do separate analyses with several functions which have adequate fit but form upper and lower bounds to the empirical data. A third way is to use truncated analytical distributions. Judgment must be used in choosing the appropriate goodness of fit test. Information on the theoretical basis for fitting distributions can be found in a standard statistics text such as Statistical Methods for Environmental Pollution Monitoring, Gilbert, R.O., 1987, Van Nostrand Reinhold; off-the-shelf computer software such as Best-Fit by Palisade Corporation can be used to statistically determine the distributions that fit the data.

- If only a range of values is known for an exposure factor, the assessor has several options.
  - keep that variable constant at its central value;
  - assume several values within the range of values for the exposure factor;
  - calculate a point estimate(s) instead of using probabilistic analysis; and
  - assume a distribution (The rationale for the selection of a distribution should be discussed at length.) There are, however, cases where assuming a distribution is not recommended. These include:
    -- data are missing or very limited for a key parameter;
    -- data were collected over a short time period and may not represent long term trends (the respondent usual behavior) - examples include: food consumption surveys; activity pattern data;
    -- data are not representative of the population of interest because sample size was small or the population studied was selected from a local area and was therefore not representative of the area of interest - examples include: soil ingestion by children; and
    -- ranges for a key variable are uncertain due to experimental error or other limitations in the study design or methodology - examples include: soil ingestion by children.

1.7 USING THE HANDBOOK IN AN EXPOSURE ASSESSMENT

Some of the steps for performing an exposure assessment are (1) determining the pathways of exposure, (2) identifying the environmental media which transports the contaminant, (3) determining the contaminant concentration, (4) determining the exposure time, frequency, and duration, and (5) identifying the exposed population. Many of the issues related to characterizing exposure from selected exposure pathways have been addressed in a number of existing EPA guidance documents. These include, but are not limited to the following:

- Guidelines for Exposure Assessment (U.S. EPA 1992a);

- Dermal Exposure Assessment: Principles and Applications (U.S. EPA 1992b);
- Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions (U.S. EPA, 1990);
- Risk Assessment Guidance for Superfund (U.S. EPA, 1989);
- Estimating Exposures to Dioxin-Like Compounds (U.S. EPA, 1994);
- Superfund Exposure Assessment Manual (U.S. EPA, 1988a);
- Selection Criteria for Mathematical Models Used in Exposure Assessments (U.S. EPA 1988b);
- Selection Criteria for Mathematical Models Used in Exposure Assessments (U.S. EPA 1987);
- Standard Scenarios for Estimating Exposure to Chemical Substances During Use of Consumer Products (U.S. EPA 1986a);
- Pesticide Assessment Guidelines, Subdivisions K and U (U.S. EPA, 1984, 1986b); and
- Methods for Assessing Exposure to Chemical Substances, Volumes 1-13 (U.S. EPA, 1983-1989).
- Guiding Principles for Monte Carlo Assessments.

These documents may serve as valuable information resources to assist in the assessment of exposure. The reader is encouraged to refer to them for more detailed discussion.

Most of the data presented in this handbook are derived from studies that targeted (1) the general population (e.g., USDA food consumption surveys); and (2) a sample population from a specific area or group (e.g., Calabrese's et al. (1989) soil ingestion study using children from the Amherst, Massachusetts, area). Due to unique activity patterns, preferences, practices and biological differences, various segments of the population may experience exposures that are different from those of the general population, which, in many cases, may be greater. It is necessary for risk or exposure assessors characterizing a diverse population, to identify and enumerate certain groups within the general population who are at risk for greater contaminant exposures or exhibit a heightened sensitivity to particular chemicals. For further guidance on addressing susceptible populations, it is recommended to consult the EPA, National Center for Environmental Assessment document: EPA/600/R-99/060 July 1999, entitled, *Socio-demographic Data Used for Identifying Potentially Highly Exposed Subpopulations*.

1.7.1 General Equation for Calculating Dose

The definition of exposure as used in the Exposure Guidelines (U.S. EPA, 1992a) is "condition of a chemical contacting the outer boundary of a human." This means contact with the visible exterior of a person such as the skin, and openings such as the mouth, nostrils, and lesions. The process of a chemical entering the body can be described in two steps: contact (exposure), followed by entry (crossing the boundary). The magnitude of exposure (dose) is the amount of agent available at human exchange boundaries (skin, lungs, gut) where absorption takes place during some specified time. An example of exposure and dose for the oral route as presented in the EPA Exposure Guidelines is shown in Figure 1-1. Starting with a general integral equation for exposure (U.S. EPA 1992a), several dose equations can be derived depending upon boundary assumptions. One of the more useful of these derived equations is the Average Daily Dose (ADD). The ADD, which is used for many noncancer effects, averages exposures or doses over the period of time over which exposure occurred. The ADD can be calculated by averaging the potential dose (D_{pot}) over body weight and an averaging time.

$$ADD_{pot} = \frac{\text{Total Potential Dose}}{\text{Body Weight} \times \text{Averaging Time}} \qquad (1\text{-}1)$$

For cancer effects, where the biological response is usually described in terms of lifetime probabilities, even though exposure does not occur over the entire lifetime, doses are often presented as lifetime average daily doses (LADDs). The LADD takes the form of the Equation 1-1 with lifetime replacing averaging time. The LADD is a very common term used in carcinogen risk assessment where linear non-threshold models are employed.

The total exposure can be expressed as follows:

$$\text{Total Potential Dose} = C \times IR \times ED \qquad (1\text{-}2)$$

Where:

C = Contaminant Concentration

IR = Intake Rate

ED = Exposure Duration

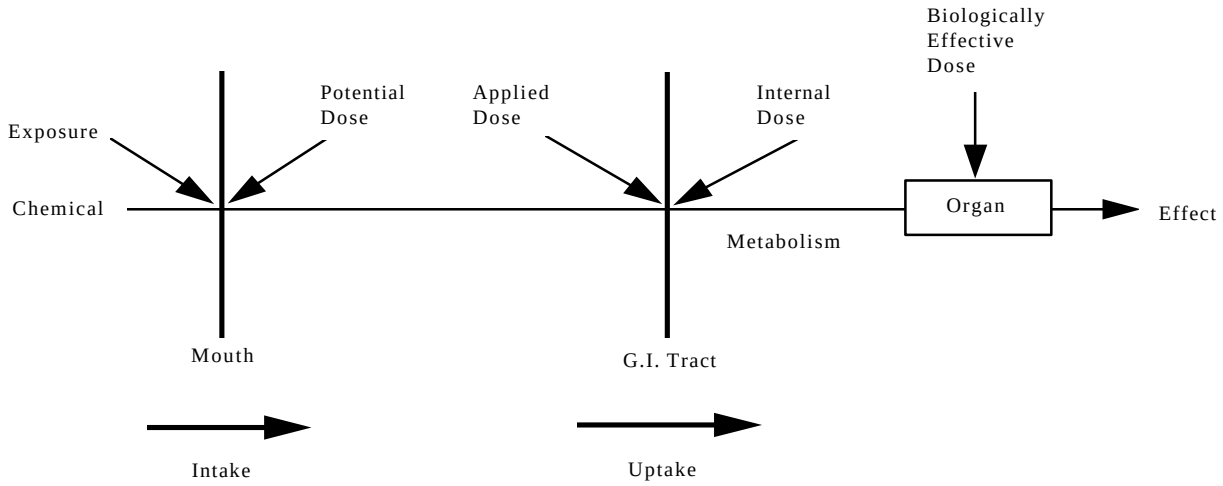

Figure 1-1. Schematic of Dose and Exposure: Oral Route

Source: U.S. EPA, 1992a

Contaminant concentration is the concentration of the contaminant in the medium (air, food, soil, etc.) contacting the body and has units of mass/volume or mass/mass.

The intake rate refers to the rates of inhalation, ingestion, and dermal contact depending on the route of exposure. For ingestion, the intake rate is simply the amount of food containing the contaminant of interest that an individual ingests during some specific time period (units of mass/time). Much of this handbook is devoted to rates of ingestion for some broad classes of food. For inhalation, the intake rate is the rate at which contaminated air is inhaled. Factors that affect dermal exposure are the amount of material that comes into contact with the skin, and the rate at which the contaminant is absorbed.

The exposure duration is the length of time that contaminant contact lasts. The time a person lives in an area, frequency of bathing, time spent indoors versus outdoors, etc. all affect the exposure duration. The Activity Factors Chapter (Chapter 9) gives some examples of population behavior patterns, which may be useful for estimating exposure durations to be used in the exposure calculations.

When the above parameter values remain constant over time, they are substituted directly into the exposure equation. When they change with time, a summation approach is needed to calculate exposure. In either case, the exposure duration is the length of time exposure occurs at the concentration and intake rate specified by the other parameters in the equation.

Dose can be expressed as a total amount (with units of mass, e.g., mg) or as a dose rate in terms of mass/time (e.g., mg/day), or as a rate normalized to body mass (e.g., with units of mg of chemical per kg of body weight per day (mg/kg-day)). The LADD is usually expressed in terms of mg/kg-day or other mass/mass-time units.

In most cases (inhalation and ingestion exposure) the dose-response parameters for carcinogen risks have been adjusted for the difference in absorption across body barriers between humans and the experimental animals used to derive such parameters. Therefore, the exposure assessment in these cases is based on the potential dose with no explicit correction for the fraction absorbed. However, the exposure assessor needs to make such an adjustment when calculating dermal exposure and in other specific cases when current information indicates that the human absorption factor used in the derivation of the dose-response factor is inappropriate.

The lifetime value used in the LADD version of Equation 1-1 is the period of time over which the dose is averaged. For carcinogens, the derivation of the dose-response parameters usually assumes no explicit number of years as the duration of a lifetime, and the nominal value of 75 years is considered a reasonable approximation. For exposure estimates to be used for assessments other than carcinogenic risk, various averaging periods have been used. For acute exposures, the administered doses are usually averaged over a day or a single event. For nonchronic noncancer effects, the time period used is the actual period of exposure. The objective in selecting the exposure averaging time is to express the exposure in a way which can be combined with the dose-response relationship to calculate risk.

The body weight to be used in the exposure Equation 1-1 depends on the units of the exposure data presented in this handbook. For food ingestion, the body weights of the surveyed populations were known in the USDA surveys and they were explicitly factored into the food intake data in order to calculate the intake as grams per day per kilogram body weight. In this case, the body weight has already been included in the "intake rate" term in Equation 1-2 and the exposure assessor does not need to explicitly include body weight.

The units of intake in this handbook for the ingestion of fish, breast milk, and the inhalation of air are not normalized to body weight. In this case, the exposure assessor needs to use (in Equation 1-1) the average weight of the exposed population during the time when the exposure actually occurs. If the body weight of the individuals in the population whose risk is being evaluated is non-standard in some way, such as for children or for first-generation

immigrants who may be smaller than the national population, and if reasonable values are not available in the literature, then a model of intake as a function of body weight must be used. One such model is discussed in Appendix 1A of the Exposure Factors Handbook (U.S. EPA, 1997b). Some of the parameters (primarily concentrations) used in estimating exposure are exclusively site specific, and therefore default recommendations could not be used.

The food ingestion rate values provided in this handbook are generally expressed as "as consumed" since this is the fashion in which data are reported by survey respondents. This is of importance because concentration data to be used in the dose equation are generally measured in uncooked food samples. In most situations, the only practical choice is to use the "as consumed" ingestion rate and the uncooked concentration. However, it should be recognized that cooking generally results in some reductions in weight (e.g., loss of moisture), and that if the mass of the contaminant in the food remains constant, then the concentration of the contaminant in the cooked food item will increase. Therefore, if the "as consumed" ingestion rate and the uncooked concentration are used in the dose equation, dose may be underestimated. On the other hand, cooking may cause a reduction in mass of contaminant and other ingredients such that the overall concentration of contaminant does not change significantly. In this case, combining cooked ingestion rates and uncooked concentration will provide an appropriate estimate of dose. Ideally, food concentration data should be adjusted to account for changes after cooking, then the "as consumed" intake rates are appropriate. In the absence of data, it is reasonable to assume that no change in contaminant concentration occurs after cooking. Except for general population fish consumption and home produced foods, uncooked intake rate data were not available for presentation in this handbook. Data on the general population fish consumption have been presented in this handbook (Chapter 3) in both "as consumed" and uncooked basis. It is important for the assessor to be aware of these issues and choose intake rate data that best matches the concentration data that is being used.

The link between the intake rate value and the exposure duration value is a common source of confusion in defining exposure scenarios. It is important to define the duration estimate so that it is consistent with the intake rate:

- The intake rate can be based on an individual event (e.g., serving size per event). The duration should be based on the number of events or, in this case, meals.

- The intake rate also can be based on a long-term average, such as 10 g/day. In this case the duration should be based on the total time interval over which the exposure occurs.

The objective is to define the terms so that when multiplied, they give the appropriate estimate of mass of contaminant contacted. This can be accomplished by basing the intake rate on either a long-term average (chronic exposure) or an event (acute exposure) basis, as long as the duration value is selected appropriately.

1.8 FUTURE OR ON-GOING WORK

EPA is also developing guidance on the use of exposure factors data. For future information on the status of this guidance, it is recommended to consult the EPA National Center for Environmental Assessment homepage (www.epa.gov/ncea). Another on-going effort is the Risk Assessment Forum project on defining age groups for children that are appropriate for use in risk assessment.

1.9 RESEARCH NEEDS

The data for several exposure factors for children are limited. The following list is a compilation of areas for future research related to childhood exposure factors:

- More recent information is needed on breastmilk consumption.

- Information on children's food handling practices that might exacerbate exposure is needed to better characterize exposures among children.

- Further research on fish intake among children, particularly recreational and subsistence populations, is needed.

- Research is needed to better estimate soil intake rates, particularly on how to extrapolate short-term data to chronic exposures. Research is also needed to refine the methods to calculate soil intake rates (i.e., inconsistencies among tracers and input/output misalignment errors indicate a fundamental problem with the methods). Additional information on soil ingestion among children that provides better estimates of upper percentile rates is needed, in particular.

- Further research is needed on non-dietary ingestion exposure factors, such as the microenvironments in which children spend time and the types of materials that they

contact, as well as information on the rate at which they contact contaminated surfaces, the fraction of the contaminants that are transferred to skin and object surfaces, and the amount of the object/skin entering the mouth.

- Additional data on dermal exposure factors, such as the microenvironments in which children spend time and the types of materials that they contact, as well as information on the rate at which they contact contaminated surfaces, and the fraction of the contaminants that are transferred to skin and object surfaces.

- Further research is needed to obtain better soil adherence rates for additional activities involving children.

- Further data is needed on the frequency of use and kinds of consumer products used by children.

- Additional information on derivation of new surface area based on newer body weight data.

- Additional data on inhalation rates that are specific to children's activities are needed.

- In cases where several studies of equal quality and data collection procedures are available for an exposure factor, procedures need to be developed to combine the data in order to create a single distribution of likely values for that factor.

- Research is needed to derive a methodology to extrapolate from short-term data to long-term or chronic exposures.

- Further research is needed to estimate food consumption rates by children based on the CSFII supplemental survey on children.

- Regarding breast milk ingestion, research is needed on incidence and duration of breast feeding.

1.10 ORGANIZATION

The handbook is organized as follows:

Chapter 1	Provides the overall introduction to the handbook
Chapter 2	Provides factors for estimating exposure through ingestion of breastmilk
Chapter 3	Provides factors for estimating human exposure through ingestion foods, including fish
Chapter 4	Provides factors for estimating exposure through ingestion of drinking water

Chapter 5	Provides factors for estimating exposure as a result of ingestion of soil
Chapter 6	Presents factors for estimating exposure to environmental contaminants from other non-dietary ingestion such as hand-to-mouth and object-to-mouth activity
Chapter 7	Provides factors for estimating exposure as a result of inhalation of vapors and particulates
Chapter 8	Provides factors for estimating dermal exposure to environmental contaminants that come in contact with the skin
Chapter 9	Presents data on activity factors (activity patterns, population mobility, and occupational mobility)
Chapter 10	Presents data on consumer product use
Chapter 11	Presents data on body weight
Chapter 12	Presents data on lifetime

1.11 REFERENCES FOR CHAPTER 1

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Table 1-1. Considerations Used to Rate Confidence in recommended Values

CONSIDERATIONS	HIGH CONFIDENCE	LOW CONFIDENCE
Study Elements		
Level of peer review	The studies received high level of peer review (e.g., they appear in peer review journals).	The studies received limited peer review.
Accessibility	The studies are widely available to the public.	The studies are difficult to obtain (e.g., draft reports, unpublished data).
Reproducibility	The results can be reproduced or methodology can be followed and evaluated.	The results cannot be reproduced, the methodology is hard to follow, and the author(s) cannot be located.
Focus on factor of interest	The studies focused on the exposure factor of interest.	The purpose of the studies was to characterize a related factor.
Data pertinent to U.S.	The studies focused on the U.S. population.	The studies focused on populations outside the U.S.
Primary data	The studies analyzed primary data.	The studies are based on secondary sources.
Currency	The data were published after 1990.	The data were published before 1980.
Adequacy of data collection period	The study design captures the measurement of interest (e.g., usual consumption patterns of a population).	The study design does not very accurately capture the measurement of interest.
Validity of approach	The studies used the best methodology available to capture the measurement of interest.	There are serious limitations with the approach used.
Study sizes	The sample size is greater than 100 samples. The sample size depends on how the target population is defined. As the size of a sample relative to the total size of the target population increases, estimates are made with greater statistical assurance that the sample results reflect actual characteristics of the target population.	The sample size is less than 20 samples.
Representativeness of the population	The study population is the same as population of interest.	The study population is very different from the population of interest.[a]
Variability in the population	The studies characterized variability in the population studied.	The characterization of variability is limited.
Lack of bias in study design (a high rating is desirable)	Potential bias in the studies are stated or can be determined from the study design.	The study design introduces biases in the results.
Response rates		
In-person interviews	The response rate is greater than 80 percent.	The response rate is less than 40 percent.
Telephone interviews	The response rate is greater than 80 percent.	The response rate is less than 40 percent.
Mail surveys	The response rate is greater than 70 percent.	The response rate is less than 40 percent.
Measurement error	The study design minimizes measurement errors.	Uncertainties with the data exist due to measurement error.
Other Elements		
Number of studies	The number of studies is greater than 3.	The number of studies is 1.
Agreement between researchers	The results of studies from different researchers are in agreement.	The results of studies from different researchers are in disagreement.

[a] Differences include age, sex, race, income, or other demographic parameters.

Table 1-2. Summary of Exposure Factor Recommendations and Confidence Ratings

EXPOSURE FACTOR	RECOMMENDATION	CONFIDENCE RATING
Breast milk intake rate	742 ml/day (average)	Medium
(1-6 months)	1,033 ml/day (upper percentile)	Medium
Drinking water intake rate	See Table 4-15 L/day (average)	High
	See Table 4-15 L/day (90th percentile)	High
Total fruit intake rate	See Table 3-2 (per capita average)	High
	See Table 3-2 (per capita 95th percentile)	Low
Total vegetable intake rate	See Table 3-2 (per capita average)	High
	See Table 3-2 (per capita 95th percentile)	Low
Total meat intake rate	See Table 3-2 (per capita average)	High
	See Table 3-2 (per capita 95th percentile)	Low
Total dairy intake rate	See Table 3-2 (per capita average)	High
	See Table 3-2 (per capita 95th percentile)	Low
Total grain intake	See Table 3-2 (per capita average)	High
	See Table 3-2 (per capita 95th percentile)	Low
Fat Intake	See Table 3-15	--
Fish intake rate	General Population	
	See Table 3-6 (total fish)	High (ave.)
	See Table 3-6 (marine)	Low (upper percentile)
	See Table 3-6 (freshwater/estuarine)	
	Recreational fish intake	
	1-5 years, 370 mg/kg/day (average)	Low
	6-10 years, 280 mg/kg/day (average)	Low
	Native American Subsistence Population	
	<5 years, 11 g/day (average)	Low
Home produced food intake	See Table 3-28	Medium (for means and short-term distributions) Low (for long-term distributions)
Soil ingestion rate	Children	Medium
	100 mg/day (average)	
	400 mg/day (upper percentile)	
	Pica child	Low
	10 g/day	
Inhalation rate	Children (<1 year)	High
	4.5 m^3/day (average)	
	Children (1-12 years)	High
	8.7 m^3/day (average)	

Table 1-2 (Cont'd). Summary of Exposure Factor Recommendations and Confidence Ratings

EXPOSURE FACTOR	RECOMMENDATION	CONFIDENCE RATING
Surface area	Water contact (bathing and swimming) Use total body surface area for children in Tables 8-1 through 8-2; Soil contact (outdoor activities) Use body part area based on Table 8-3	High High
Soil adherence	Use values presented in Table 8-13 depending on activity and body part (central estimates only)	Low
Life expectancy	75 years	High
Body weights for children	Use values presented in Tables 11-3 and 11-4 (mean and percentiles)	High
Body weights for infants (birth to 6 months)	Use values presented in Table 11-1 (percentiles)	High
Showering/Bathing	Showering time 10 min/day (average) 1 shower event/day	High
Swimming	Frequency 1 event/month Duration 60 min/event (median)	High High
Time indoors	Children (ages 3-5 years) 19 hr/day Children (ages 6-14 years) 20 hr/day Children (ages 12-17 years) 19 hrs/day	Medium High
Time outdoors	Children (ages 3-5 years) 2.8 hr/day Children (ages 6-8 years) 2.2 hr/day Children (ages 9-14 years) 1.8 hr/day Children (ages 12-17 years) 19 hr/day	Medium High

Table 1-3. Characterization of Variability in Exposure Factors

Exposure Factors	Average	Upper percentile	Multiple Percentiles	Fitted Distributions
Breast milk intake rate	✓	✓		
Total intake rate for major food groups	✓	✓ Qualitative discussion for long-term	✓	
Individual food intake rate	✓			
Drinking water intake rate	✓	✓	✓	✓
Fish intake rate for general population, recreational marine, recreational freshwater, and Native American	✓	✓		
Serving size for foods	✓	✓		
Home produced food intake rates	✓	✓	✓	
Soil intake rate	✓	Qualitative discussion for long-term		
Inhalation rate	✓	✓	✓	
Surface area	✓	✓	✓	
Soil adherence	✓			
Life expectancy	✓			
Body weight	✓	✓	✓	
Time indoors	✓			
Time outdoors	✓			
Showering time	✓	✓	✓	
Occupational tenure	✓			
Population mobility	✓	✓	✓	